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"Black Box" Recorders for Extreme Wind Events

FY 2003 Proposal to the NOAA HPCC Program

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Proposal Theme: **Disaster Planning, Mitigation, Response and Recovery**

Funding Summary: FY 2003 $46,000 (100% match requested from Sea Grant)

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"Black Box" recorders for Extreme Wind Events

Proposal for FY 2003 HPCC Funding

Prepared by: Mark D. Powell

Executive Summary:

A consortium has been formed around the concept of preserving high resolution wind observations during extreme coastal wind events. Members of this group include universities from coastal states with atmospheric science or wind engineering programs in partnership with the NOAA Hurricane Research Division of AOML, the National Hurricane Center/Tropical Prediction Center and the National Data Buoy Center of the National Weather Service. This project will systematically outfit the United States Coastal-Marine Automated Network with "blackbox" devices to allow threshold-activated, automatic recording of extreme winds at a 2 Hz rate, and real-time transmission of the maximum one minute wind over each hour. The data sets will be used to document the peak winds experienced at a site during extreme wind events and contribute toward research on the fine scale structure of turbulence and its relationship to wind loading of structures.

Problem Statement:

Real-time information on the occurrence of an event (based on the exceedance of some pre-determined weather threshold) is needed to allow forecasters to advise emergency managers and other decision makers so they can properly respond and organize recovery, restoration, and even search and rescue efforts. Unfortunately, peak wind information currently transmitted in real-time from Coastal-Marine Automated Network stations is not consistent with the framework used in the forecast and warning cycle of the National Hurricane Center (maximum 1-min sustained wind), and detailed, fine-scale information on the highest winds is not documented. If a hurricane passes over our "picket line" of C-MAN stations, it is not currently possible to monitor or document the highest wind experienced at the station.

Proposed Solution:

For the C-MAN network in hurricane threatened locations, enable communication of the maximum 1 min wind in real-time and outfit the network with "black box" recorders that can document the wind record at high enough frequency (1-2 Hz) to determine turbulent structure characteristics. A definitive path is in place for porting C-MAN data to N-AWIPS workstations. NDBC will seek authorization to add a new code group to the C-MAN format, and begin engineering changes to the observing equipment.

NDBC has redesigned their approach to obtaining a nonvolatile record of wind speed measurements in extreme wind events with the goal of simplifying the process and reducing the recurring expenses. The requirement for the "Black box" is to record the wind direction and speed every 0.5 seconds at these 19 C-MAN stations south of Cape Hatteras during a land falling hurricane:

	Station Identifier	Location Name
1.	PTAT2	Port Aransas, Texas
2.	SRST2	Sea Rim State Park, Texas
3.	GDIL1	Grand Isle, Louisiana
4.	BURL1	Buras, Louisiana
5.	DPIA1	Dauphin Island, Alabama
6.	CSBF1	Cape San Blas, Florida
7.	KTNF1	Keaton Beach, Florida
8.	CDRF1	Cedar Key, Florida
9.	VENF1	Venus, Florida
10.	DRYF1	Dry Tortugas, Florida
11.	SANF1	Sand Key, Florida
12.	SMKF1	Sombrero Reef, Florida
13.	LONF1	Long Key, Florida
14.	MLRF1	Molasses Reef, Florida
15.	FWYF1	Fowey Rocks, Florida
16.	LKWF1	Lake Worth, Florida
17.	SAUF1	St. Augustine, Florida
18.	FBIS1	Folly Beach, South Carolina
19.	CLKN7	Cape Lookout, North Carolina

We propose to use an improved time series data recorder (TSDR) to store all wind directions and speeds from the onset of hurricane force winds until after their abatement. In order to reduce recurring expenses, there will be no cellular or satellite communications with the TSDR and data retrieval will require a site visit. However, the TSDR will pass some information through the payload for relay through GOES: The peak five second wind gust, the peak half second winds, and the highest one minute average observed in the last hour. This will allow us to:

a) Automatically verify the proper performance of the TSDR,

b) Determine the peak half second winds which will help us to determine whether to proceed with data retrieval, and

c) Distribute the peak one minute wind to NCEP's Tropical Prediction Center in real-time to help in their verification efforts. Peak one minute winds are the basis for TPC's hurricane advisories.

Total development costs for a 19 station network would be $159 K. This would provide $16K for the software and engineering development costs and $5.7 K for the cost of 19 C-MAN units and 6 spares. All engineering, design, and manufacturing of the units will take place at NDBC's facility located on the campus of the Stennis Space Center in Mississippi. Project management and travel costs would be contributed by NDBC, with costs minimized by handling deployments and retrievals during regular maintenance visits.

The observations associated with this program will help fill a huge gap in our knowledge of the turbulence experienced during high wind events. Data will be made available to all co-investigators through an ftp site and will be used to support research and educational programs in meteorology and wind engineering at the listed universities and NOAA facilities. Co-investigators are encouraged to visit HRD to collaborate on investigations and share data gathered by the annual HRD Hurricane Field Program.

Analysis:

Infrastructure components can be designed to withstand extreme events if sufficient information is available to fully describe both the likelihood of experiencing an event, and the physical interaction between the weather and structure or system. Engineering and design of structures and transportation and communication systems to withstand extreme weather episodes is dependent on an understanding of the cycling of loading associated with gusts and lulls during extreme wind events like hurricanes and winter storms. Lack of extreme wind data and full scale information on structural wind loading has forced engineers and designers to rely on wind tunnel studies to provide the needed information (NRC 1999), but fine scale observations are needed to determine the validity of wind tunnel experiments, and to help specify more realistic full scale testing of structural components. Since the end of the analog era and advent of digital recording, high resolution "strip-chart" type recordings of extreme wind events are no longer archived and no information is preserved on the fine-scale turbulent structure of strong winds (Powell 1993). In fact, the highest U. S. wind record yet preserved in digital, fine resolution form is below minimal hurricane force.

The likelihood of experiencing an event depends on the accuracy of the climatic record for such events, and the ability to model risk based on this record. The insurance industry depends on this climatology to establish the probability of extreme wind events that drive the cost of premiums. The design, engineering, and construction industries also depend on this climatology since building codes have regional and local dependencies associated with the probability of extreme wind events. Unfortunately, the wind observing network in the United States is to a large extent designed to support aviation and not for documenting extreme wind events. Every major hurricane landfall is accompanied by failed anemometer systems. In the area near Hurricane Andrew's eyewall during landfall in south Florida, most of the wind measurement systems failed for a variety of reasons including lack of back up power and poor mounting of the anemometer masts (Powell et al., 1996). The NDBC network of automatic coastal stations (C-MAN) are the only operational network in the U.S. designed from the bottom up for performance in extreme conditions. Measurement and communication payloads are designed to operate in harsh marine environments and redundant sensors provide additional capacity. Despite this capacity, the station at Fowey Rocks failed in 1992 after Hurricane Andrew smashed all the windows in the 44 m tall lighthouse and toppled the anemometer mast. Fowey was able to transmit observations shortly before the eyewall passed over but no archival was possible in between hourly satellite transmissions. Had a "black box" been available for Fowey Rocks, a complete high-resolution wind record would have been available up to the point of failure of the wind mast, and we would have had a much better idea of Andrew's maximum winds.

If the United States wind records do not contain a true measure of extreme winds or if stations fail when winds reach peak levels, the ramifications can be wide spread structural failures due to insufficient design capacity, insolvency of insurance companies, and increased deaths and public suffering. All this was experienced in Hurricane Andrew ten years ago but little has been done to rectify the limitations of the observing system to provide the best possible record of the extreme wind experienced at our coastal stations: the peak one minute winds are not recorded and there is no high resolution record from which turbulent wind loading information may be extracted. A short-lived U. S. Weather Research Program (USWRP) effort attempted to solve this problem and was successful in recording events in Hurricanes Floyd, Dennis, and Irene in 1999, but design limitations and high recurring costs associated with cellular phone communications prevented continuation of the program. The USWRP is now focused on "test bed" activities to transition promising research to operations. The proposed network eliminates recurring communication costs. Units will be deployed and retrieved manually within NDBC's routine maintenance schedule. Peak 1-min winds transmitted in real-time to NHC will take advantage of existing GOES satellite communication bandwidth and will require only minimal software changes.

The enhanced C-MAN network will help supplement a hurricane "chase" program already in progress with consortium members Texas Tech, Clemson, University of Florida, and Florida Institute of Technology. The chase programs attempt to strategically place anemometer systems ahead of approaching storms. The latter three universities are participating in a program with the State of Florida to instrument coastal residences for full scale wind loading. Sea Grant is supporting the development of wireless remote pressure sensors associated with that effort.

Performance Measures:

Milestones:
1. Outfit eleven (11) coastal C-MAN stations in 2003 (and fabricate 2 spares)
2. Successful real-time transmission of maximum 1 min wind observations from outfitted stations
3. Successful documentation of high wind events from tropical cyclones or other severe weather

Deliverables:
1. Engineering, design, and testing of "Black Box" recording devices (Document)
2. Deployment of black boxes on C-MAN stations in areas susceptible to extreme winds from hurricanes.
3. Upon documentation of an event, data will be made available to investigators (via FTP site) within 30 days of retrieval.

Project-Related References:
Powell, M. D., P. P. Dodge, and M. L. Black, 1991: The landfall of Hurricane Hugo in the Carolinas. *Weather Forecast*., 6, 379-399.

Powell, M. D., 1993: Wind measurement and archival under the automated surface observing system (ASOS): User concerns and opportunity for improvement. *Bull. Amer. Met. Soc.*, 74(4), 615-623.

Powell, M. D., S. H. Houston, and T. A. Reinhold, 1996: Hurricane Andrew's Landfall in South Florida. Part I: Standardizing measurements for documentation of surface wind fields. *Weather Forecast*., 11, 304-328.

Coauthor, NRC Committee Report: 1999: Review of the need for a large-scale test facility for research on the effects of extreme winds on structures. National Research Council, National Academy Press, Washington D. C. ISBN-0-309-06483-X.

2003 Budget Summary:

Provide a summary of the proposed budget.

Category	Detailed Description	Amount
Capital Expenses	Engineering, design and testing	$16k
	Fabrication/deployment 11 sites and 2 spares	$76k
Requested from HPCC:		$46 k
Matching requested from Sea Grant:		$46k
Total requested:		$92k

Potential recurring costs for 2004:

Category	Detailed Description	Amount
Capital Expenses	Fabrication/Deployment of remaining Black boxes at 8 sites (and 4 spares)	$70k

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